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JOURNAL

OF

THE ENGINEERING SOCIETY

OF

THE LEHIGH UNIVERSITY.

ISSUED QUARTERLY.

APRIL, 1887.

JOURNAL

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EDITORS FOR THE SOCIETY:

E. S. Stackhouse, '86,

B. A. Cunningham, '87,

L. R. Zollinger, '88,

Charles C. Jones, '87, *Business Manager.*

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ABSTRACT OF PROCEEDINGS.

Thursday, P. M., February 17, 1887.—President LaDoo in the chair. Mr. Jones reported that the *Railroad Gazette*, and a recent Treatise on Locomotives had been added to the Society Library. Mr. Jacoby, Instructor in Civil Engineering, read a paper on the "Blue Print Process," and gave a description of a frame of his own design. For this paper the Society passed a vote of thanks. Mr. Sattler, '88, read a paper on "Artificial Fuel," and Mr. Reisler, '87, one on "Meteorites."

Thursday, P. M., March 3.—The President had the chair. Twenty-three members were present. The President reported having received several engineering pamphlets. Mr. Spalding, Instructor in Civil Engineering, presented a paper on "Accurate Methods in Railroad Surveying," and received a vote of thanks from the Society. Mr. Howard, '87, made an interesting report of the recent visit of the Mechanical and Mining Engineers to New York and Stamford, Conn.

Thursday, P. M., March 17.—The President in the chair, and seventeen members were present. Mr. Lara, '86, a visitor. Minutes of two previous meetings read and approved. The project for obtaining a room for the Society was discussed, and the President instructed to confer with the Mechanicals in regard to

the Society using a room of theirs. The President gave some valuable suggestions on choosing subjects for papers. Mr. Sattler was appointed to collect subscriptions for the JOURNAL.

Thursday, P. M., March 31.—Meeting was called in Professor Merriman's room. The President and Vice-President being absent, the Secretary took the chair. Fifteen members were present. Minutes of previous meeting read and approved. Mr. Stackhouse read a paper on "Glacial Evidences in Eastern Pennsylvania."

Thursday, P. M., April 14.—President LaDoo took the chair. The room question was further discussed, but no conclusion reached. Prof. Doolittle read an instructive paper on "The Precision of Numerical Computation," for which he received a vote of thanks. By motion, meetings will hereafter be held Thursday evenings at 7 o'clock.

MASON D. PRATT, *Secretary.*

THE BLUE PRINT PROCESS.

Read before the Society by H. S. Jacoby, Instructor in Civil Engineering.

The Blue Process is spoken of under various names, such as the cyanotype, the ferro-prussiate, or the blue copy process. Heliography is the general term applied to actinic copying, whether the result is shown in white lines on a colored ground, or colored lines on a white ground; the color of either lines or ground being generally blue or black, although other colors may be produced by using different chemicals.

We shall confine our attention this evening to *that* process of copying drawings, resulting in white lines on a blue ground, which, on account of its simplicity and cheapness, has led to its general use in Engineering offices. As a number of inquiries from different sources have led to the adoption of this subject, I shall endeavor to make this talk as practical as possible, by giving chiefly the results of my own experience.

Brief Outline of the Process.—Having prepared a sheet of flat paper by means of a sensitizing solution, a tracing of the drawing to be copied is laid upon this and exposed to clear sunlight for a while in a printing frame constructed for this purpose. The sheet is then washed in clear water for a few minutes, when the

characteristic blue color appears and the lines of the drawing are shown in the natural color of the paper before it was sensitized.

The Tracing.—This may be made either on tracing paper or linen. In general, that material is preferred which is the most transparent and at the same time strong enough to stand the necessary handling. Sagar's Patent tracing cloth is more transparent than the Imperial. Many draughtsmen prefer the linen having a dull finish on one side, as the lines drawn on that surface are more apt to be uniform in thickness and additions can readily be made in pencil and inked afterwards. Always remove the selvedge from the cloth. The tracing should be executed in Indian ink that is perfectly black. The liquid Indian inks sold by stationers answer the purpose very well, but the addition of gamboge will improve their opacity. Very fine lines should be avoided, and if the scale is large enough all the lines may be made heavier than in the original drawing. Scales should be drawn on the map instead of being simply indicated. To guard against the unequal contraction of the paper, two scales, at right angles to each other, should be drawn. Tracings should be kept flat or rolled, as folding renders the material opaque at the folds or prevents perfect contact with the sensitized paper in the printing frame.

The Sensitizing Solution.—Dissolve 1 ¼ ounces of red prussiate of potash in 8 ounces of water and keep it in a stone bottle. Dissolve 1 ⅞ ounces of citrate of iron and ammonia in 8 ounces of water and keep it in a separate bottle. When ready for work take equal parts of these solutions and pour them into an earthen, glass, or agate-iron dish. It is best not to mix more than is required at the time as the combined solution, even if kept in the dark, will soon deteriorate, changing its color from yellow to green.

The above proportions are not absolute. We are told that Herschel, the inventor of this process of copying, used 1 ounce of the red prussiate of potash to $1\frac{1}{6}$ ounces of the citrate of iron and ammonia and a total of 8 ounces of water, thus making a saturated solution. Mr. Channing Whittaker, in the *Journal of the Association of Engineering Societies*, for August, 1882, stated as the result of numerous experiments that the best results were obtained by using 2 parts of the red prussiate of potash to 3 parts of the citrate of iron and ammonia and 20 parts of water. From my own observations I conclude that slight changes in the

proportions of the chemicals or the strength of the solution will produce less variation in the character of the blue print than lack of attention to the details of the process.

Preparing the Paper.—On an inclined surface, such as that of the developing bath to be described hereafter, fasten by a tack in each upper corner of the paper as many sheets as it is desired to prepare. Apply the solution by means of a sponge about the size of the hand, covering the surface of the sheet by rapid strokes back and forth having the sponge nearly saturated. Now press it nearly dry and in the same manner go over the sheet again, thus removing all the surplus liquid. This leaves only a thin coating of the solution of a bright yellow color. To obtain a covering of uniform thickness it is necessary that the paper have sufficient sizing not to allow the solution to sink beneath the surface provided the work is done rapidly.

The sheet is now dried by suspending it from a line by small clamps at the corners. Proceed in like manner with the next sheet which is already in position. In Summer the paper will dry rapidly enough, but in Winter the room should be well warmed. When this is done the room will not need to be entirely dark, but sufficient light to do the work may be admitted. Gas light will not injure the paper. Care should be taken not to touch the back of the sheet with the sensitizing solution. It is also well in Winter to warm the solution before applying it.

Kind of Paper.—When the paper is well sized it may be comparatively soft in texture. When it is unglazed it is necessary that its texture should be solid so as to prevent the sensitizing solution from penetrating it. When the paper is porous and the liquid strikes through it, it is very difficult to remove the chemicals that still remain soluble after the exposure to light in the printing frame, and when these are not entirely removed the copy assumes in a short time a dirty greenish cast. As blue prints can be reproduced so readily it is not generally required that they shall be made on very strong paper.

The cheapest paper that will give good results is sized and super-calendered book paper, the minimum weight being 75 pounds to the ream for sheets 28 by 42 inches in size. I find that a cream-tinted paper gives better blue copies than the plain white of the same weight and quality.

Bond paper is very strong and will bear rough handling. As its surface does not regain its smoothness after treatment with

the solution, but becomes irregular or wavy, it often prevents perfect contact between some of its parts and the tracing when placed in the printing frame. Bond papers varying in thickness from No. 16 to No. 22 give very satisfactory copies.

Ledger papers of light or medium weight are more easily manipulated in sensitizing and printing. When the sheets are small the price is about the same as for bond paper, but for large sheets the cost is about double.

Of the paper specially manufactured for this purpose, one brand is cheaper than ledger paper, another is dearer and several others are offered at about the same price.

The Printing Frame.—The principal parts of a printing frame consist of a glass plate, a plane surface covered with a slightly yielding material, and some arrangement for exposing the same to the sunlight. For printing only occasional copies the apparatus may be very simple in character, but it pays to have as convenient arrangements as possible for offices requiring considerable work of this kind. For small copies a photographer's printing frame answers every purpose. Larger frames of the same pattern are also manufactured.

The University possesses a large frame of the best type, so arranged that its surface may always be placed perpendicular to the rays of the sun and the prepared paper and tracing are kept in contact by the pressure of an inflated air cushion. As the members of this Society may examine that apparatus for themselves, I shall now show you the plans and describe briefly one of my own design whose cost is very much less than that of the other, and therefore within the means of a larger number.

A board 28″ x 45″ x 1½″ was first constructed of narrow strips of thoroughly seasoned pine, having two cleats on the back about 4 inches wide, and 22½ inches apart between centers. After being stored away in a warm room for some time, the surface was again planed down very carefully. It was then covered with one thickness of woolen blanket and on top of that was stretched a sheet of rubber packing. A rest for the plate-glass frame was attached underneath one end of this pad by two cleats. The glass measured 30″ x 48″ x ⅜″, and was enclosed in a frame 2½ inches wide. The pad and its plate-glass cover were carried on a car that rolled easily on a track extending out of the southern window of the room. The longitudinal timbers in the frame of the car were 15 inches apart between centers.

In order to raise the glass easily a rope with a hook at each end was passed over a pulley at the ceiling of the room. One extremity of a small chain having a ring in the middle was fastened on each side of one end of the plate-glass frame. One end of the rope being drawn down and hooked into the ring of the chain, by pulling on the other end the glass is raised until the other hook can be inserted in the ring. As one end of the framed glass is supported by the rest attached to the pad, and the other suspended from above, there is nothing to interfere with the insertion and removal of the prepared paper and tracing beneath the glass. By extending the floor of the car even with the exterior of the frame and inserting several wooden pins along the edges, continuous rolls of tracing can be copied.

The Printing Process.—Darken the room; place the tracing with a sensitized sheet under it, between the glass and pad, and see that there are no wrinkles or folds in the tracing. Wrinkles can frequently be removed by a slight lateral movement of the glass-plate. The blinds are then opened, the truck bearing the frame pushed out of the window and exposed to clear sunlight for three or four minutes in Summer or from four to six minutes in Winter. If the sunlight is not clear the time of exposure must be increased. Its duration can generally be determined from the changing color of the edge of the paper projecting beyond the tracing. Experience will enable the operator to do this with reasonable accuracy. After the print is sufficiently exposed the truck is drawn into the room and the sheet removed from the frame. It will be noticed that the effect of the light has changed the yellow color to a dark bronze and the lines of the drawing are darker still. The shade of the blue copy after washing depends upon the time of exposure. If the print is *not* exposed long enough the shade will be light, and if exposed beyond the usual limit the color becomes a very dark blue and finally becomes grayish.

The Bath.—This consists simply of a water-tight wooden box or tray 52 inches long, 42 inches wide at one end and 39 inches at the other, and 6 inches deep. This size is adapted for sheets 28 x 42 inches. The tray is fastened by hinges to the wall and supported so as to give its bottom a slope of about 30°. A trough extends from the opening in the lower corner to the waste pipe. When not in use the tray may be let down so as to be out of the way.

Developing the Print.—When the print is taken from the frame it is laid in this tray and by means of a small hose a stream of water is directed on the sheet until its color is changed to a clear blue and all the remaining soluble chemicals are washed off. The development may be hastened by using warm water. The blue tint may be intensified by using a dilute solution of hydrochloric acid ($3\ HCl + 100\ H_2O$) and washing again with water. By using a slender lattice frame on the floor of the bath the sheets may be washed without wetting the other side of the paper, which will allow the use of a lighter paper than is required when the sheets are submerged in a bath. From one and one-half to two minutes are ordinarily required by this method for washing prints on highly calendered book paper, some other papers requiring more time. The same is true when the sensitized paper has been prepared for some time. After being thoroughly washed the print is hung up to dry.

Changes can be made on the blue copy by using a tint of Prussian blue in a right line pen to cover up white lines, while a tint of Chinese white applied in the same way will produce white lines on the blue ground. Dilute solutions of carbonate of soda, carbonate of potash, or chloride of lime will also produce white lines.

At present most of the time is consumed in making the tracing from which to print. For a large class of drawings the necessity of a tracing may be obviated by using a special transparent parchment upon which the original drawing is made. This paper has a fine dull surface, well adapted to the use of pencil and pen, while pencil marks are readily erased. If it is stretched in the usual manner and then dampened with rectified turpentine, the transparency of the paper is increased. Sections and profiles can also be copied without tracing by using sectional tracing paper.

Cost of the Sensitized Paper.—For the purpose of comparison the prices of the following papers, both prepared and unprepared are reduced to the cost per sheet measuring 28 by 42 inches. The book paper referred to above may be purchased at 1.5 cents, antique wove thickness No. 16, 5.1 cents, and bond paper of the same thickness at 6.1 cents. Various papers manufactured specially for this purpose cost from 8 to 25 cents unprepared and from 26 to 43 cents when prepared.

Any one desiring to prepare his own paper may do so at a

cost for the book paper of 1.3 cents per sheet, the chemicals costing 0.5 cents, (with the red prussiate of potash at 60 cents per pound and the citrate of iron and ammonia at 85 cents per pound), while 0.8 cents covers the cost of labor at 32 cents per hour. As the price of book paper is 1.5 cents the total cost when prepared is 2.8 cents per sheet. As bond paper absorbs a larger quantity of the solution its cost when prepared would be about 7¾ cents per sheet. H. S. JACOBY.

METEOROIDS AND METEORS.

Meteoroid is a comparatively new word used by Newcombe to specify those invisible bodies now known to be moving through interstellar as well as interplanetary space, once supposed to be void. They range in weight from a few grains to several hundred weight.

Meteor is the term used for the phenomena produced by meteoroids colliding with the earth's atmosphere, and include shooting stars, detonating meteors, and aerolites.

The meteoroids, supposed to be moving indefinitely through space, are drawn into orbits about the sun by his attraction and become, for a time at least, a part of the solar system. We are only made aware of the presence of these bodies by the flashes accompanying their destruction when they come in collision with the earth. Our astronomy tells us that the average meteor enters the atmosphere with a velocity of twenty miles per second, becomes visible at an elevation of seventy-five miles and disappears while still fifty miles above the surface, remaining visible through about forty miles of its path. It is evident that the time during which such a body is visible is very short and any satisfactory observation of it extremely difficult. But, fortunately, of the ten millions of these bodies daily entering our atmosphere, three or four in the course of a year reach the earth in fragments large enough to be closely examined by chemists and microscopists. The results of analyses have shown meteorites to contain no new elements, but the constituents occur in forms that completely separate them from terrestrial rocks. In many respects they resemble volcanic rocks, a fact that was the foundation for the now abandoned theory that aerolites came originally from volcanoes either on the earth or the moon.

The most important constituents are Silica, Iron, Magnesium, Manganese, and Aluminium. Carbon should also be mentioned since this element is oxidized in passing through the air and the product, with the CO_2 already in the air, goes to support vegetable life. Hence any variation in the amount of CO_2 from this source will have a direct effect upon vegetation and also upon animal life.

As the meteor enters our atmosphere, the resistance of the air diminishes its velocity with the production of enough heat to melt the outer layer of the body, which layer is immediately carried off in melted globules by friction of the air. Successive layers are thus melted and carried away until, unless the meteor be unusually large, the body is entirely dissipated, Those large enough to withstand the passage through one hundred miles ot atmosphere fall to the surface as aerolites. Very often the sudden heating causes the meteor to explode, and if the explosion is heard at the surface of the earth, the phenomenon is called a detonating meteor.

The melted globules left behind the meteor cool quickly and fall unnoticed toward the earth. But the iron of meteors occurs unoxidized and always with nickel and cobalt, a distinctive difference from terrestrial iron. Its detection is therefore easy and globules of meteoric iron are found everywhere on the earth's surface as well as in the air. They occur in dust from the air collected on vessels in mid-ocean and on mountain peaks miles from any dwellings or manufactories. They are found in dust on snow in the Arctic regions and in mud dredged from the bed of the ocean. As the iron is the only ingredient of meteoric dust that can be detected, the amount of such dust in the air can not be separated from the atmospheric dust from other sources. But, as before stated, the estimated number of meteors large enough to be visible to the naked eye at night is ten millions daily and their estimated weight one hundred tons. This daily supply added to a mass of six sextillions of tons must continue for millions of years before its effect would be appreciable. In 80,000 millions of years, the increase of the earth's mass would be sufficient to lessen the moon's period of revolution about the earth one second. The same proportional change in the length of the earth's period would amount to a second in 7000 millions of years. Small as these effects are, yet they have a tendency to disturb the present rates of motion in the solar system, and are therefore worthy of consideration.

It is observed that meteors come mostly from that point in the heavens toward which the earth is moving in its orbit about the sun. These meteors must then have the same effect as a resisting medium and so will finally result in precipitating the earth into the sun. The other planets would sooner or later suffer the same fate.

Again, assume the average velocity of these one hundred tons of meteors before striking the earth to be twenty miles per second and that by this collision they are brought to a state of rest. The amount of energy thus changed into other modes of motion is $\frac{1}{2}Mv^2$ equal to nearly thirty-five trillions of foot-pounds daily. These figures are really too small, because, as above stated, most of the meteors *meet* the earth and hence have a velocity of twenty miles per second in one direction changed to a velocity in the opposite direction nearly as great. But taking the above value and reducing to heat-units by dividing by Joules' equivalent, we have enough to heat 29,900,000 gallons of water from freezing to boiling point. This does not, of course, bear comparison with the amount of energy constantly received from the sun, but even infinitesimal causes acting through indefinitely long periods produce appreciable effects. It is, therefore, of interest to know whether our supply of meteors is liable to any considerable change, and to investigate this matter requires some knowledge of the origin of meteors, farther than that they are caused by meteoroids colliding with our atmosphere. A few meteors, about four an hour, may be seen any clear night. But, not infrequently, showers of meteors are observed. These showers differ from the others in that their visible paths, if marked upon a star map and produced backward, intersect in a point showing that the bodies were moving in a common orbit. Certain of these showers are periodic, hence their orbit must be elliptic. Many of these orbits coincide with the orbits of comets, but it is at first rather difficult to see what connection can exist between solid bodies like meteoroids and nebulous comets. The following theory, though built up on a rather narrow foundation of fact, accounts very satisfactorily for this connection. Whether future investigation will strengthen or undermine this foundation, remains to be seen.

Assume space through which small meteoroids and large bodies of gas, elements of comets, are moving in various directions. A meteoroid collides with the gas, plunges through it,

but by the superior mass of the gas is retained in an orbit about its center. At every passage of the meteoroid through the gas, its motion is retarded and the orbit becomes smaller until the meteoroid finally comes to rest at the center of the gas. Numberless meteoroids do likewise. By and by, the now completed comet comes within reach of our sun's powerful attraction and moves towards it. Such a comet passed very close to Uranus in January, 1826, and its orbit was changed from a hyperbola to an ellipse with a period of 33¼ years. This orbit cuts the earth's orbit at a point which the earth passes November 13 or 14. In passing Uranus, in addition to the change in its orbit, the interior of the comet was much disturbed. The immense swarm of meteoroids, being at slightly different distances from the planet, had their motion in the new orbit accelerated in slightly different degrees, thus causing a tendency in these bodies to separate from each other and from the comet. The result of this tendency has been that this swarm of meteors is now elongated until it requires about three years to pass the point of intersection with the earth's orbit. We therefore had an exceedingly brilliant shower of meteors for three consecutive years, when these meteors last passed this point, in 1866, '67, and '68. At one place the number estimated to have been visible in three hours was 240,000. This shower of meteors will continue to increase in length and decrease in brilliancy until the meteors are distributed throughout the entire orbit, when we will have a shower every year when the earth passes the point of intersection. Such is now the case with the August meteors. These meteor showers, therefore, seem permanently attached to the solar system, for even if the comet originally accompanying them should be again interfered with by Uranus and the comet sent off in an orbit beyond the earth's orbit at every point, it would not affect any considerable part of the ring of meteors. The only change that can be expected in meteor showers is that due to their distribution throughout their orbit, and possibly a small decrease in number from the meteoroids destroyed at every shower. The addition of a new shower may also occur at any time.

But the greater number of meteors, the irregular supply, seems to come from independent meteoroids moving through space. Now, suppose the sun in his journey at the rate of twenty-five miles per second should enter a territory almost void of meteoroids. Our supply of one hundred tons of meteors daily would

almost entirely cease, and if the famine continued for many thousand years, who can deny that the loss of heat from their destruction might result in another glacial epoch. Or, on the other hand, suppose the sun to carry us into space thickly populated with meteoroids, a milky way of these bodies, and be a million of years getting through them. The additional heat and perhaps increase of CO_2 would favor the occurrence of another carboniferous period.

E. T. REISLER.

AN ARTIFICIAL FUEL AS A SUBSTITUTE FOR NATURAL GAS.

The solution of the problem of finding a fuel, which would be more economical, as well as more advantageous than those in use at the present day, is one that has long been sought-for. And although there have been a great many patents taken out, which the inventors hoped would fill these requirements, there are only two, which to my knowledge, come at all near doing so.

These are: The water-gas system, invented about fifteen years ago; and the more recent invention of Mr. E. S. Burgess, which by the use of a very simple apparatus burns the hydro-carbon oils, and obtains from them a more intense heat than that derived from any natural fuel. It is to the latter that I wish to draw your attention.

To begin with, I will go through a brief description of the apparatus. It is very simple, consisting of two pipes; one leads from the water supply, forming a coil in the bottom of the fire box to an ejector, where it unites with the second pipe leading from the oil tank. There are also two domes, one for the maintenance of an even pressure upon the water, and the other for the purpose of keeping the pressure of steam uniform at the point where it issues from the ejector, after having been generated in the coil before referred to.

The arrangement is as follows: The first pipe conducts the water from the city supply, when the pressure is sufficiently great, and when not great enough, directly from the boiler, to a dome about 8″ in diameter, and 14″ high. The pipe leading from the dome is a ¾″ extra hydraulic pipe, and enters the furnace at one

side of the ash-pit, forming a coil resting on the bottom of the furnace, and leaving it again at the other side of the ash-pit. The steam generated in this coil passes on through the pipe to a second dome of same dimensions as the first, and to the ejector.

The second, a ⅜″ pipe leads directly from the oil tank to the ejector, the flow of oil being regulated by a needle valve located between the tank and the ejector.

Another needle valve, regulating the quantity of water admitted to the coil, is located between the water dome and the coil.

The ejector is a double tube, two forms of which I have shown; the interior tube is connected with the oil tank which supplies the oil by gravitation, the exterior one being connected with the coil from which it receives the superheated steam. The ejector passes through the front of the furnace, and is so turned, that the steam and oil are hurled into a combustion chamber, built of fire brick, or other refractory material, on the inside of the furnace.

In this chamber the combustion takes place, the heated gases pass over the slab, which covers the combustion chamber and come in contact with the heating surface.

The apparatus, as you will readily see, is so simple that besides its cost being merely nominal, it can be set in a few hours after the fire has been allowed to go out and the furnaee is sufficiently cool to allow the men to build the combustion chamber.

In starting a fire all that is required is to throw a few sticks and shavings on the coil and to light them. In a very short time the coil is sufficiently hot to generate steam. The needle valve is opened slightly and water allowed to enter the coil, where it is immediately converted into steam. In a few minutes, the pressure will be sufficiently great to cause it to rush forth from the outer tube of the ejector in the form of a cylindrical jet. The needle valve regulating the flow of the oil from the tank is now slightly opened, and the oil allowed to enter the interior tube of the ejector. Here it is caught by the escaping steam, and in the form of carbon vapor it is hurled into the combustion chamber, where it ignites. In a few minutes the coil, both from the effect of the flame and the heat radiated from the combustion chamber, becomes very hot, and instead of the ordinary steam we get dry superheated steam; or oxygen and hydrogen hurling, not vapor but heated carbon gases into a red hot combustion chamber,

which holds the resultant gases until their combustion is completed; at which time, the greatest possible result is attained in the form of an oxy-hydro-carbon flame of perfect whiteness. After the fire is started it is easily controlled by means of the needle valves.

Many who have not seen the apparatus or who do not understand its working, ask if the intense heat of the flame striking the boiler continually in one place does not injure the boiler plates. In reply to this I would say that the flame does not strike the boiler at all, but only the walls of the combustion chamber, the heated gases passing out over the slab covering the chamber. Besides this heat the walls of the combustion chamber radiate the heat they absorb from the flame.

The gases generated do not act on the iron plates of the boiler, so that besides the freedom from danger of burning out from the direct action of the flame, they are not liable to suffer from external corrosion.

The advantages which this fuel has over coal are:

1. Its cheapness. Taking as an example a boiler requiring, say two tons of coal per day, at a cost of three dollars per ton, the annual cost of running this boiler would be $1800.

The oil fuel system would require only four gallons of oil at seventy-five cents, which is rather a high rate; this would make the annual cost $900. A saving of $900 per annum, besides the superior heat and other advantages. That this can be done has been proved in every instance.

2. The fire can be controlled with very little trouble by a man or boy of ordinary intelligence. On steamships, where the number of stokers is very large, the number can be cut down to at least one-fourth.

3. The heat produced being uniform, produces an even generation of steam; hence, in running an engine, where regularity of action is necessary to produce uniform speed of the machinery, it is always reliable.

It is not necessary to open the fire doors to put on fuel, as in furnaces heated by coal and there is therefore no sudden rush of cold air against the heated plates.

4. The fire, as we have before stated, is free from sulphurous, ammoniacal and other gases, and in its action upon the boiler plates it is therefore less destructive than that of coal or wood. This quality also renders it of great value in metallurgical processes and in glass blowing.

5. When the apparatus is working fairly well, there is almost complete combustion, and there are no foul gases, cinders or smoke.

In cities the cost of removing ashes is very great; this expense is done away with by the system.

6. Ocean steamers are saved the space required for storing the great bulk of coal necessary for fuel purposes. The tanks for the oil can be located in any part of the hold, and it only requires a line of pipe to bring the oil to the feed tank. If necessary a small pump can be used to draw the oil from the lower tanks. Should it be desirable to equalize the effect produced by employing tanks, it can easily be done by filling them with water.

Numerous tests have been made in New York, Philadelphia and other places, and the results have proved highly satisfactory. Its economy varying only with the price of fuel in different localities.

W. R. Sattler.

THE GREAT GLACIER.

Geology is eminently a science of theory; we look about us and study the rocks exposed to our view to-day and from their structure, associations, form, etc., by a process of reasoning, determine the conditions under which they were formed millions of years ago.

The short time of man's observations, a few thousand years at most, is the fulcrum upon which he rests his lever, theory, and raises before us the great amount of facts that are accepted by geologists to-day. Thus we see what a small basis we have to reason upon, and are not surprised to learn that many of the theories of a quarter of a century ago have been replaced by more perfect and more modern ones; and so geology, although well established in its great general laws and facts, is constantly undergoing changes, or we might say, is being polished and rounded off more and more in its details, as new facts appear and new discoveries are made. There is a class of phenomena observed in the Northern and Eastern parts of our country, and among the latest geological formations, that is very peculiar.

Among these phenomena are:

1. The vast quantities of drift or unstratified gravel, sand, clay and bowlders, occurring in these regions.

2. The occurrence of large bowlders or masses of rocks at a distance from their formation, and sometimes at heights greatly above those of their normal occurrence. A familiar instance of this in the anthracite coal regions is the occurrence of large bowlders of conglomerate or millstone grit, which was formed under the coal, scattered over the surface above the coal measures.

3. The existence of scratches or groovings on the surface rocks and of large egg-shaped pot holes. These phenomena are very common, and without a satisfactory explanation would seem very mysterious.

But as before stated, we study the facts that are presented to us, the results of the action of various forces in operation many thousand years ago, and decide from the known action of such forces to-day under similar conditions, what was the cause of the phenomena. This is precisely what we do in this case; taking the known data, we seek for an explanation of the cause; there are two theories:

First, The Iceberg Theory, which supposes New England to have been submerged 5,000 feet or more below its present level. This does not seem so reasonable, nor does it account so well for the effects that have been produced, as the other, so we will drop it and turn our attention to the

Second, or Glacier Theory, which supposes the Northern part of this country to have been covered by an immense glacier, of vastly greater magnitude than any of the present day. This theory is sustained by facts brought to light from the study of known glaciers, principally of those in the Alps. Thus, glaciers are known to transport bowlders, gravel, etc., make scratches, and in fact the phenomena of a modern glacier and those of which we have spoken, are in nearly every way similar.

We will now speak of the nature of glaciers, and the conditions that enable them to move up hill as well as down, for such is the case. A glacier should not be thought of as a large rigid mass of ice, but as an ice stream fed by the snows and frozen mist of regions above the limits of perpetual frost. They stretch on 4,000–7,500 feet below the snow line, or limit of perpetual snow, because they have such magnitude that the heat of the Summer season is not sufficient to melt them. Each glacier is the source of one or more streams made from the melting ice; this is a point that should be noticed, as we will refer to it again in connection with our local geology.

Dana gives the following as the conditions essential to glacier formation:

"1. The region must extend above the line of perpetual congelation.

2. Abundant moisture is as essential as for rivers; abundant precipitation in Winter especially favors their formation.

3. A difference of temperature and moisture between Summer and Winter is requisite; for otherwise the snows will be melted to the same line throughout the year, and will not extend much below the line of perpetual congelation. The lower limit of a glacier sometimes varies several miles in the course of a series of years. A series of moist years increases the thickness of the glacier, and thereby its tendency downward; while dry years have the reverse effect."

The law of flow of glaciers is essentially that of rivers, so we will say no more about it except that the flow depends on the slope of the upper surface, which is determined ordinarily, partly by the supply of snow to the glacier and partly by the slope and form of land beneath it, but the latter slope is not absolutely necessary to movement. All that is needed is a general slope of the upper surface of a glacier, whatever may be the slope of the surface of the earth; this point is illustrated very nicely by dropping pitch on an inclined surface, confined below, when the pitch will gradually flow up the incline as the height below increases. The reasons for the capability of motion in a glacier are:

1. A kind of plasticity in ice, which may be made through pressure, like wax, to occupy a seal or mold, and if a number of broken pieces of ice are submitted to a high pressure, they will be cemented together so as not to show that they had been broken.

2. The ease with which ice breaks, thus easily accommodating itself to new forms of surface and mending its fractures easily by a freezing together again of the surfaces in contact, a process called regelation. Crevasses are the result of this law, for when a glacier meets a sudden change of slope, there is a fracture produced which freezes together again on coming to a regular slope below.

3. The capability of certain portions only sliding along its bed at a time.

4. Pressure lowers the freezing point of water, so that with increase of pressure, greater cold is required to keep ice solid; hence, wherever there is a strain occasioned by the obstacles to movement in a glacier, the ice melts, relieving the resistance and facilitating motion.

We will now return to the great glacier of North America. Agassiz, over 40 years ago, after a prolonged study of the Swiss glaciers, was the first to announce that large portions of North America and Europe were covered in recent geological times by immense glaciers; geologists were at first startled by this improbable hypothesis, but to-day there is hardly a truth in geology more widely accepted or capable of more conclusive proof.

Report Z, of the Second Geological Survey of Pennsylvania, by H. C. Lewis, is on the Terminal Moraine of this glacier in Pennsylvania; accompanying this report is a map showing the course of the moraine across the State, with the direction of flow as determined by the striations, together with the heights. The general direction of flow in Eastern Canada and New England was South-east; in Eastern New York it was South; while in Western New York and Central Pennsylvania it was South-west. The intersection of these directions shows that the probable summit was over the Canada water-shed, nearly North of Montreal. In Western Pennsylvania the course was South-east and this probably had another source in the Western part of Canada.

The ice contained large quantities of stones, bowlders, etc., probably uniformly distributed throughout its mass, and at the melting point these bowlders were dropped, forming terminal moraines; while the smaller stones, pebbles, drift, sand, clay, etc., were carried off and deposited farther down by the glacial streams which must have run in torrents from the melting glacier.

The terminal moraine gives us a good and accurate method of determining the limit of the glacier; it has been traced by Mr. Lewis and the general course is as follows: Starting from Perth Amboy in New Jersey it goes in a North-west direction, crossing the Delaware River at Belvidere, still following northwesterly, crossing the Lehigh about ten miles above Mauch Chunk, the Susquehanna at Beach Haven, a short distance below Shickshinny, in Luzerne County, and in the same direction until it crosses the State line near the North-west corner of Potter County into New York State, and continues for a distance of about fifteen miles from the State line where it turns and trends southwesterly, again crossing the State line near the North-eastern corner of Warren County into Pennsylvania, and again crossing the Western boundary of the State near the North-western corner of Beaver County into Ohio. It leaves Pennsylvania at exactly the same latitude as it enters, and the highest point reached in New York is about

one hundred miles North of this parallel of latitude. It came within sixty miles of Philadelphia and thirty-five miles of Pittsburgh. The formation of Wind Gap, a short distance North-east of Bethlehem, has always been a puzzling question to geologists; it lies nearly on the terminal moraine and is no doubt the result of the glacier.

There is a small brook coming down the hill back of South Bethlehem, and through the lower part of the University lands, all along which are large bowlders of many different kinds of rocks. That they are from a distance is proved by the fact that many are from formations foreign to this immediate vicinity. I found along here rocks of clay slate, hornblend-schist, hornstone, basalt, etc., which have no doubt been washed down from the glacier by a torrent rushing down through this hollow. It must indeed have been a large stream running with a very great velocity to have transported such large bowlders 40–60 miles.

Bowlders similar to these have been found far down along the Mississippi River; it is thought that oftentimes large masses of ice would break off and floating down the streams would deposit the enclosed rocks upon melting.

There have been many other phenomena noticed as the result of the glacier besides those spoken of; such are roches moutonnies or sheep backs, hills rounded off by the scraping action of the glacier; moraine lakes or ponds produced by the damming up of water courses, kames, etc.

The pot holes before spoken of are formed by the wearing produced by stones revolving by the action of water from a glacial torrent. These are smooth and often of large dimensions, one at Archibald in the anthracite coal regions being 20 feet in diameter and 40 feet deep.

One of these that has been brought especially to our notice, was the cause of the mine accident at Nanticoke over a year ago, by which a number of men were shut in the mine. A pot hole had been covered with quicksand (the result of the grinding together of stones by the glacier) and then a large dirt bank had been started on the surface above it. The immense weight of this mass at last broke through the thin roof at this weak place and filled the mine with quicksand mixed with culm, which ran almost as freely as water.

It is supposed that the formation of Long Island was caused by the glacier, this being a terminal moraine, and it is composed of large bowlders of various sizes.

There are still other phenomena which are the direct result of this very interesting geological period, but I have not the time to dwell on them here; to those who care to look the subject up farther, Report Z, mentioned above, will prove very interesting.

We will now notice certain astronomical facts which at least indicate what might have been the cause of this intense cold.

The effect of precession tends to make the axis of the earth revolve about the axis of the ecliptic; a complete revolution being made in 25,868 years; but there is a motion of the line of apsides in the opposite direction, a complete revolution being made in 110,000 years; hence the cycle of the seasons is shortened to about 21,000 years. Also the eccentricity of the earth's orbit varies, and it has been shown that a maximum eccentricity occurred 110,000 years ago, when the earth was 13½ millions of miles nearer the sun in Summer than in Winter. We can easily see that if the inclination of the earth's axis was in the proper direction at a period of maximum eccentricity, long cold Winters and short hot Summers would be the result.

E. S. STACKHOUSE.

THE PRECISION OF NUMERICAL COMPUTATION.

Read before the Society by Prof. C. L. Doolittle.

In the practical applications of Mathematics we meet with two classes of problems. The first, for want of a better name, we may call Analysis. The object in view is a theoretical investigation for the purpose of establishing relations between the quantities sought and other quantities whose values may be regarded as known. As the result we shall have equations and formulæ in which the quantities, known and unknown, will be expressed by means of symbols and in which the relations will be exact, provided our premises and methods are reliable.

The problems which comprise the second class we may include under the general term, *Computation.* Our object is to express the numerical values of the quantities which in our formulæ are indicated by symbols. Instead of proceeding with rigorous accuracy we are obliged in this work, except in some simple cases, to content ourselves with an approximation to the truth. So far as accuracy depends upon computation we can generally

push the approximation as far as we please. In the application this generally reduces to the retention of a greater or less number of decimals, or a greater or less number of terms of a series. In a computation involving a considerable number of operations the labor increases very rapidly with the increase in the number of figures retained, and even if we are willing to spend weeks in computing the value of π to some hundreds of decimal places the result is only an approximation in the end.

In consequence, however, of the errors to which our data will always be liable, we very soon reach a limit beyond which nothing is gained by increased accuracy of computation. If for instance, instead of a theoretical relation between the circumference of a circle and the radius, we wish to know the actual circumference of a circle whose radius has been measured, it is evident that we can not attain a more accurate knowledge of the circumference than that which we have of the radius. It would therefore be a simple waste of energy to retain a number of decimals in the value of π employed much beyond the degree of accuracy of our measured radius.

The advantage of knowing something of the relations between the errors of our data and those likely to be introduced in the computation is apparent. Otherwise we are liable on the one hand to waste much time in useless refinements and on the other to loss of accuracy by the neglect of important terms. An inexperienced computer is perhaps more liable to error in the first of these directions than in the second.

We may recognize some general principles to guide us in this matter, though it may not be possible to establish general rules which shall be universal in their application. We shall generally have an idea from some source of the kind of errors to which our data are liable. The methods and instruments employed and the care with which measurements have been made will generally enable us to draw some conclusion in regard to it. In more refined investigations an examination of the precision of the instrument, of personal errors and other disturbing causes will frequently lead to quite definite conclusions. While in some cases an investigation of the probable errors by the methods of least squares may be advisable. By whatever method we have arrived at our idea as to the magnitude of the errors of the data we may regard the following rule as of very general if not universal application. Carry out the computation throughout,

so that the errors from this source shall be one degree less in magnitude than those of the data.

Thus, if we have a series of measurements which give us four accurate figures, a computation based upon them should be carried out accurately to five places. In order to reach this degree of precision we shall be obliged to retain a greater number of decimal places, when the computation involves a large number of operations, than when the number is small, to guard against the accumulation of small errors.

Suppose by way of illustration that we have the algebraic sum of several quantities, a, b, c, whose value is given to the nearest unit. Let us determine how many such quantities we can combine before the probable error of the algebraic sum amounts to one unit.

The decimal part of our quantities having been rejected, each is too great or too small by one of the following quantities, one decimal place only being retained,

$$.0 \quad .1 \quad .2 \quad .3 \quad .4 \quad .5$$

and the probable error of each is $\pm .25$.

The probable error of the algebraic sum of n such quantities will be $\pm .25 \sqrt{n}$ which equals unity when $n = 16$.

Suppose now our quantities given with a precision one degree greater, the errors now being $.00 \pm .01 \pm .02 \pm .03 \pm .04 \pm .05$. The probable error of a single quantity is now $\pm .025$, and of the algebraic sum of n quantities $\pm .025 \sqrt{n}$ which is equal to unity when $n = 1600$.

If then we are satisfied with a degree of accuracy which gives a probable error of one unit, we need not carry our determination of the individual values farther than the units place unless the whole number to be combined equals 16. If it is greater than 16 we must carry out the values one place farther. It must not be forgotten that the possible errors of such algebraic sums much exceed these values, thus, if the possible error of the algebraic sum is not to exceed unity, we shall reach it with the addition of two quantities, as each may be in error .5 and the errors may be in the same direction. The possible error of the sum of 16 such quantities being 8.

Let us apply these considerations to logarithmic computation. In order to make our remarks more definite suppose a five place table employed. The mantissa taken from such a table may be too large or too small by any one of the quantities .0 .1 .2 .3 .4

.5 expressed in units of the last place. The probable error of the tabular value is therefore $\pm .25$. But when the value is interpolated between two of the tabular quantities, the probable error is a little greater than this. We may call the probable error of a mantissa in general $\pm .3$. If then our computation calls for the employment of n such logarithms we shall have for the probable error of the algebraic sum $\pm .3\sqrt{n}$ which $= 1$ when $n = 11$.

In taking from the table the number corresponding to a given logarithm this probable error of .3 will affect the fifth place of the result by a much smaller quantity near the beginning than near the end of the table. Thus for the mantissa .00000 an error of .3 in the last place produces an error of 0.07 in the fifth place of the corresponding number, while for the mantissa .99999 the error is 0.70. In case of a large number of mantissas uniformly distributed, the mean value of the probable error of the corresponding number is $\pm .31$.

Suppose now our data to be reliable to three places, the fourth being uncertain. If a computation based upon such data require 10 logarithms to be taken from the table, we may feel reasonably confident that a computation with five places will introduce no errors above the fourth place, which will therefore in ordinary cases suffice. If then in general we have a logarithmic computation to make, based upon data which we may regard as reliable to n places, by employing an $n + 1$ figure table, we may feel pretty confident that the n^{th} figure of our result is reliable, provided the number of logarithms involved does not exceed 10. If, however, a greater number than 10 has been employed, or if the last figure is very important, we should employ a table of $n + 2$ figures.

In a similar manner we may inquire to what decimal our computation must be carried out in order to produce a given degree of precision when angular measurements are in consideration. In taking from the table the logarithm of a trigonometrical function corresponding to a given angle, we find the same result for the probable error as in case of the logarithm of a natural number, *viz.*, ± 0.3 in units of the last place.

In taking from the table an angle corresponding to a given logarithmic tangent, this probable error will produce the maximum effect for the angle 45°, diminishing in both directions towards 0° and 90°. For a 5-figure table the probable error .3 produces a probable error of $0''.7$ at 45°, while at 1° or 89° it only

amounts to $0''.025$. In case we wish the nearest second we should therefore employ six places unless our angle comes near $0°$ or $90°$, in which case five figures or less will give the necessary precision. If the angle is small it may be accurately determined from its sine, if near $90°$ from its cosine. In other cases an angle should not be determined from these functions except where extreme accuracy is not demanded.

Logarithms of more than seven places will not be used except for some special investigations. With seven-place logarithms an error of 1 in the last place of the logarithmic tangent will produce an error of $0''.023$ in the corresponding angle for $45°$, diminishing to $0''.0008$ at $1°$ or $89°$. We may therefore feel considerable confidence in our results to tenths of seconds unless a considerable number of operations are involved, in which case the tenths may be uncertain for angles near $45°$. Numerous rules and precepts will be found for approximate computations of various kinds, some of these are useful, others not especially so. Special rules will not long remain in the memory unless they find frequent application, and as a general thing it is not worth the while to give much attention to them until the time comes when they are wanted. I will give only two rules of this character, *viz.*, for multiplication and division.

It frequently happens that we require the product of two numbers, each consisting wholly or in part of a number of decimals. We shall generally want the value accurately to a certain number (n) of decimal places. The following rule was given by Oughtred more than 200 years ago.

Rule.—Take either factor for the multiplier and write it with its figures in reverse order under the multiplicand and in such a position that the original simple units figure of the multiplier shall come under the $(n + 1)^{th}$ decimal of the multiplicand. Begin each partial product of the multiplying figure into the figure of the multiplicand directly over it, rejecting the figures of the multiplicand to the right of this, but correcting this product, if necessary by adding to it whatever would have been carried over if the other figures had been retained, and place the partial products with their right-hand figures in a vertical line. The sum of the partial products will have $(n + 1)$ decimals, the last of which will be doubtful.

Example.—Required the product of $\pi \times \sqrt{3}$ to four decimal places.

Here $n = 4$. Taking $\sqrt{3} = 1.73205$ as the multiplier and proceeding according to the rule we have the following:

$$\begin{array}{r}
3.14159 \\
\underline{50237.1} \\
314159 \\
219911 \\
9425 \\
628 \\
\underline{16} \\
5.44139
\end{array}$$

Division.—A dividend and divisor being given, it is required to form the quotient so that the absolute error shall not exceed a unit of the n^{th} decimal place.

We first determine the position of the decimal point as follows: Observe how many places to the right or left the decimal point of the dividend would have to be moved in order that the first figure of the quotient should be simple units. If the point would have to be moved n places toward the right the first significant figure of the quotient will be in the n^{th} decimal place. If the point would have to be moved n places towards the left the first figure of the quotient will be n places above simple units. That is, the true quotient will have $(n + 1)$ figures to the left of the decimal point.

We now count the whole number of figures which the quotient must contain from the first figure inclusive down to the n^{th} decimal place. Take now in the divisor a number of significant figures greater by one than the number just counted, and proceed in the usual way with the division except that instead of bringing down a figure from the dividend at each step of the process we drop off one from the divisor.

Example.—Required $\sqrt{3} \div \pi$ to four decimal places.

The first significant figure is .5, therefore the divisor should contain $(4 + 1) =$ five figures.

The process is as follows:

$$\begin{array}{r|l}
1.73205 & 3.1416 \\
\underline{157080} & .55133 \\
16125 & \\
\underline{15708} & \\
417 & \\
314 & \\
103 & \\
\underline{94} & \\
9 &
\end{array}$$

The reasons for both of these rules will be readily seen by performing operations in the usual manner and comparing the results with those given by the approximate processes.

Many books and pamphlets have been written on approximate and abridged arithmetical operations of which I will mention only the "Principles of Approximate Computations," by Joseph J. Skinner, C.E., of the Sheffield Scientific School. C. L. D.

ACCURATE METHODS IN RAILROAD SURVEYING.

Read before the Society by F. P. Spaldind, Instructor in Civil Engineering.

In all surveys there is more or less of error. In work done with the finest instruments, by the best observers, in the most careful and painstaking manner, errors exist, so small, perhaps, that they are scarcely appreciable, but they are constantly present and are to be guarded against, and where great accuracy is required to be taken into all calculations.

But in the ordinary surveys upon which engineers are commonly engaged, these small inaccuracies, due to the limitation of the powers of observer and instrument, will be entirely inappreciable, and work containing no others may be considered as perfectly accurate. Neglecting, therefore, these unimportant errors, which cannot be eliminated, we find in ordinary railroad surveys a wide variation in the degree of accuracy attained, due to a difference in the methods employed, in the care exercised by those doing the work and in the instruments used.

The accuracy of the results of any survey will therefore depend mainly upon the methods employed. Those performing the work will naturally accommodate themselves to these methods, and will exercise care and give attention to accuracy in their work in proportion as the method is one chosen for the purpose of attaining accuracy, or for the purpose of accomplishing the work rapidly and cheaply, and the nature and quality of the instruments used will in general be decided by the same considerations.

Engineers differ widely in their methods of surveying for railroads, especially in making preliminary surveys, some advocating a hasty line with a compass, taking in only the prominent features of the country, and amounting to little more than a recon-

noissance, while others run a transit line with the most scrupulous care, producing an accurate topographical map of the country through which the line is to be located; the one party claiming that the cheap line is as good for their purpose as the more expensive one, while the others consider the cost of the survey as too small an item in the general cost of the road to make it necessary to economize in this direction.

The object of making a preliminary survey is to obtain such a knowledge of the country to be traversed that the best line for the purpose may be located; the whole question is therefore simply one of relative economy.

In nearly all engineering works economy is the prime consideration. The first question to be settled regarding any proposed enterprise is, "Will it pay?" and having decided that the investment will be a paying one, it then becomes necessary to so execute the work as to make the net income a maximum, and this is the problem to be met in railroad location.

A road is to be built connecting two points. It will probably have a certain traffic, which is first determined by an examination of the business interests of the terminal points and of the country through which the line will pass.

The problem before the locating engineer is to determine the position of that line for which the annual expenses, with this given traffic, will be a minimum.

The annual expenses which will be affected by a change in the position of the road are, the interest and the cost of construction, and such portions of the operating expenses as are dependent upon the work done in hauling the traffic over the road. We have here two conflicting elements, for that line which is easiest to construct will rarely be the best to operate, and it is at once evident that their relative importance is dependent upon the amount of the traffic, and that a greater sum can profitably be expended in improving the road for the purpose of reducing operating expenses upon a line with a large, than upon one with a small, traffic.

Now, by comparing the line to be located with similar existing roads, the probable value of the operating expenses can be determined. A portion of this expense will be directly proportional to the length of line, and other portions will be proportional to the amounts of grade and curvature. Deducing this annual cost for a unit of length, the sum upon which it is the annual interest

will be the amount that may be expended in increased cost of construction for the purpose of reducing the length by one unit. The values of reducing the grade and curvature may be deduced in a similar manner.

The field operations of making a railroad location consist usually of three parts, *viz.*, the reconnoissance, the preliminary survey, and the location. The reconnoissance is a careful, general examination of the country through which the line is to pass, to determine from its general features the feasible routes, to select the ruling gradients to be tried upon the surveys, and to decide upon the controlling points for each line. These points may be the summit of a pass through which the line must go, a crossing on an important stream, or a town whose trade is considered important.

The problem of location has now assumed a more definite shape; having given two terminal points, they are to be connected by a line passing through certain intermediate points; the grade of this line is not to exceed a certain maximum; a certain known sum may be expended in reducing the length of the line one foot, and other known sums in reducing the amount of grade one foot, or of curvature one degree.

It will also be necessary at any point of the line which is upon maximum grade, where a curve is to be introduced, to lessen the grade a certain amount in order that the traction on the grade and curve combined may not exceed that upon the maximum grade alone.

The second operation in the field is the preliminary survey; the conduct of this survey and the location is usually entrusted to assistant engineers who are furnished with the necessary data as derived from the reconnoissance.

It is the intention of this paper simply to call attention to the methods in common use for making this survey, and more especially to those points upon which engineers differ most widely in their practice.

The field work of the preliminary consists in running an angular line on the chosen route which shall as nearly as possible meet the requirements of the given data, in taking elevations of a sufficient number of points in the line to make a profile of it, and in taking notes of the adjacent topography, with the side slopes at right angles to the line, or such elevations to the right or left of the line as may be of assistance in placing the location.

The topography notes usually consist of sketches of the features of the country near the line; in some cases the topography may be sketched by the transitman, while the levelman takes the slopes and side elevations; in others separate men are employed for this portion of the work. These notes vary from rough sketches made by eye, in rough work, to the extreme accuracy to be obtained by carefully measured offsets in the better class of work.

There are two methods in common use among engineers for running the angular line. It may be roughly run with a compass and chain, the chainmen getting a foresight and lining themselves in, place stakes at each chain length until they reach the end of a course, when they obtain a new foresight and go ahead as before, the compassman merely taking the bearings of the various courses. This rough method is also sometimes followed when a transit is substituted for a compass and angles are read instead of bearings. This method has been extensively used and is advocated for preliminary work by some of the leading authorities on railroad engineering.

The second method uses the transit and chain, or steel tape, with about the same party organization as the first, but the work is done more accurately; the chainman is placed in line at each chain length by the transitman, angles are carefully measured and bearings usually taken for a rough check; greater accuracy is sometimes obtained in the angular work by double centering in turning the angle from the last course, which consists in turning off the angle from the backsight and setting the point ahead, then repeating the operation with the instrument turned about 180°—the correct center will then be half way between the two points set. In rough country each chainman should carry a plumb bob to be used in taking the measurements where it is necessary to elevate one end of the chain above the ground.

From this survey, with side notes taken with a corresponding degree of accuracy, a map may be drawn, and it will then be possible to determine upon this map, in the office, the best position for the location, with its relation to the preliminary, and to calculate certain checks upon the work of location, by reference to points of the preliminary line, to be used in running the line in the field.

When the location is to be made upon a preliminary line run by one of the rough methods, the map will not possess sufficient

accuracy to admit of the location being placed upon it in the office as in the other method, and the actual work of placing the line, and determining upon the position of its curves must be done in the field upon running in the location ; and in general the time saved in the work of running the rapid preliminary will be more than counterbalanced by that used in locating from the imperfect line.

Apart, therefore, from the fact that a good location can more readily be placed upon an accurate line, it seems probable that in the majority of cases the actual cost of the survey itself by the rough method will be the greater.

There is a strong tendency on the part of American engineers toward more accurate methods in their work, as it becomes more and more evident that there is no economy in a rough and cheap survey, even for a light and rudely constructed line.

A preliminary line upon which a location is to be placed should be run as accurately as the location which is to follow it. Common practice has not as yet reached this point, though the tendency is in this direction, and some of the leading engineers have been using the more accurate methods for a number of years.

It frequently happens that it is necessary to run lines for the purpose of merely determining the feasibility of a route, or of getting general ideas of country, in order to effect comparisons of various lines ; or it may be required to locate a line in open country where the exact position of the road is not of so much consequence, and in such cases it may be advisable to run rapid cheap lines, leaving out of sight the minor consideration of accuracy in the details.

It is not intended to convey the idea that the location of a railroad is a mathematical problem to be solved by the application of a formula, or that the use of a correct method for the survey is all that is needed to insure a good line. The proper placing of the preliminary line upon the ground is a matter requiring judgment and experience, but with proper care on the part of the locating engineer the line may usually be run very nearly in the position that will be found advisable to follow with the location. The proper placing of the location upon the map is still more a matter requiring the exercise of judgment, but the problem is much simplfied if there be a correct map to locate upon.

In fixing up a method for any survey it is necessary to consider

the purpose of the survey. If a bridge or tunnel is to be built, the work must be more exact than if it be only the center line of a cut or fill, and it will pay only to put such amount of time and money in a survey as is necessary to keep the results within that limit of error which may be allowable in the given work.

F. P. Spalding.

THE EAMES VACUUM BRAKE.

At the present time railroad men are taking a great deal of interest in power brakes, especially in their application to freight trains, as may be seen from the extended series of tests made at Burlington, Iowa, July, 1886, under the direction of the Master Car Builders' Association. The final tests to be made April, 1887, will doubtless prove of very great interest and value, as showing how far in their present state of perfection power brakes are applicable to long trains of freight cars.

The brake, which is the subject of this paper, was one of the six competitors in the tests referred to, and is now in practical application upon a great many railroads in this country and South America, including the elevated roads of New York and the cars upon the Brooklyn Bridge.

Under this head are manufactured two brakes—what is known as the *plain* brake and the *duplex* brake.

The plain brake is one whose action is controlled by the engineer, and has no automatic action independent of the engineer in case of accident to the train. Its construction is very simple, its application and release instantaneous, and in its operation it is exceedingly effective. It consists of the *ejector*, the *diaphragms*, and the connecting hose and pipes.

The ejector is attached to the boiler in such a position that its two levers are most convenient to the hand of the engineer. It is also connected by pipe with the diaphragms attached to the transom of the truck, or body of the car. The function of the ejector is to produce a vacuum in the diaphragms, and its arrangement is like that of two cylinders of unequal lengths, the shorter one being of much less diameter, and placed inside the larger one. The opening between the two is contracted near the upper end, and wholly closed at the lower end of the small cylinder.

By movement of a lever steam enters the outer cylinder, passes through the contracted orifice by which its velocity is greatly accelerated, and produces a current which sucks the air out of the inner pipe and diaphragms. When the steam is shut off a check valve holds the vacuum produced.

The brakes are released by admitting air through a valve placed below the check valve and controlled by a lever.

The diaphragm consists of a kettle-shaped iron casting with a loose disc of heavy rubbered duck fastened over its mouth by means of a ring and cap screws; the center of the disc being provided with washers and an eye bolt for attachment to the brake lever.

A vacuum having been produced in the inner pipe and diaphragms by the blowing of the ejector, the pressure of the atmosphere forces the rubber disc into the iron shell and sets the brakes.

The duplex brake is a plain or straight air brake and an automatic brake combined, and may be applied and released from any part of the train as well as from the engine. The essential difference between this and the plain brake already described is in the cylinders placed beneath the cars, and into which the diaphragms may be exhausted by movement of the ejector lever and *are* exhausted automatically in case of accident.

The mechanism of the duplex brake comprises nearly all employed in the plain brake, the principal exception being the substitution of an ejector of another form. This ejector, together with the cylinders and two valves which control the passage of air between the cylinders and diaphragms, are the additional features necessary to convert the *plain* into the *duplex* brake.

The ejector used consists of the plain ejector already described, together with an additional small ejector for maintaining a vacuum in the cylinders.

The two ejectors act independently of each other, or may be used together when speedy creation of a vacuum in the cylinders, is necessary.

To maintain a vacuum in the cylinders requires the constant operation of the small ejector, and the amount of steam necessary is that which passes through an opening $\frac{5}{32}''$ in diameter.

For economical and efficient braking, *power* is an absolute necessity; that the Eames Brake has this, practically to an unlimited extent, is evident, but how much of this power it is advantageous to apply, is simply a question of railroad practice and experience.

Air is admitted and exhausted from the cylinders and diaphragms in its normal condition, consequently there is no unusual tendency to deposit its moisture, which by freezing would interfere with the working of the brake.

The release must follow immediately after the admission of air to the vacuum, and dragging of the brakes cannot occur, owing to insufficient length of stop.

Its effectiveness is illustrated by the fact that upwards of eighty thousand stops are made with it daily upon the elevated roads of New York where the brake service is known to be severe.

C. J. Parker.

WITH the appearance of the next number of the JOURNAL the present Board of Editors retires. On the whole, we think it has been a successful year for the JOURNAL, and the seed planted in June, 1884, is certainly developing and bringing forth good fruit. There are but a few things we should like to see different. One is to have every Alumnus paid up on the subscription list. The first three numbers have been sent to all, but the proportion of those who have remembered to send us the fifty cents is small. Don't neglect to send because it is such a small sum; they count up very materially for us. Another little matter is in regard to papers for publication. A great many were promised us by graduates in the early part of the year, but we are sorry to say that only a few of these promises have become realities. We have been left to depend mainly on our own resources, backed by the substantial aid of our Professors and Instructors. We would ask those who have promised us papers to try and get them in for the June number. Don't be afraid that we have too much matter on hand.

ANOTHER testimonial of the worth of the JOURNAL and the merit of the papers published in it is the republication, in the last Report of the Secretary of Internal Affairs of the State of Pennsylvania, of the paper of Mr. M. D. Pratt,'87, entitled "Rainfall at Bethlehem, Pa."

WE have received a very kind letter from Mr. W. H. Boardman, of the *Railroad Gazette*, accompanied by the much-appreciated gift to the library of our Society of "Illustrations and Descriptions of Recent Locomotives," a large and elaborate work, and a very valuable addition to our collection. We return our hearty thanks to Mr. Boardman.

WE will publish in the next number the officers of the Society elected to serve the ensuing year, giving the name and post-office address of the Business Manager, so that there will be no trouble about knowing to whom to send communications, etc., before the appearance of the first number of the JOURNAL next term.

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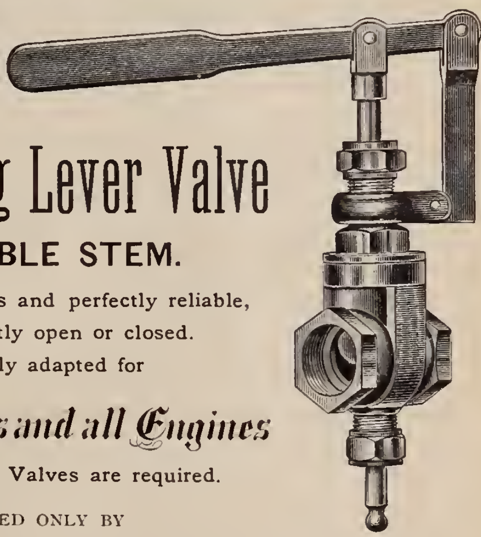

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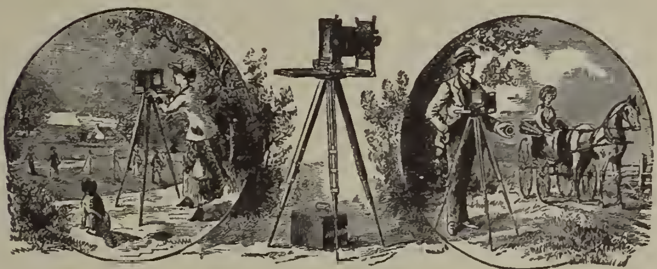

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